Inter (Part-I) 2021

Physics	Group-II	PAPER: I
Time: 2.40 Hours	(SUBJECTIVE TYPE)	Marks: 68

SECTION-I

2. Write short answers to any EIGHT (8) questions: (16)

(i) Define precision and accuracy.

Ans. The precision of a measurement is determined by the instrument or device being used while the accuracy of a measurement depends on the fractional or percentage uncertainty in that measurement.

(ii) Write down the two uses of dimensional analysis.

Ans Following are the two uses of dimensional analysis:

1. We can check the correctness of a given formula or an equation and can also derive it.
2. Dimensional analysis makes use of the fact that expression of the dimensions can be manipulated as algebraic quantities.

(iii) Calculate the volume of the cube and its uncertainty whose edge length is 2.25 ± 0.01 cm.

Ans

$$r = 2.25 \pm 0.01 \text{ cm}$$

Absolute uncertainty = Least count = $\pm$ 0.01 cm

$$\%\text{age uncertainty in } r = \frac{0.01 \text{ cm}}{2.25 \text{ cm}} \times 100 = 0.4\%$$

Total percentage uncertainty in V = $3 \times 0.4 = 1.2\%$

Thus volume $V = \frac{4}{3}\pi r^3$

$$= \frac{4}{3} \times 3.14 \times (2.25 \text{ cm})^2$$

$$= 47.689 \text{ cm}^3 \text{ with } 1.2\%$$

uncertainty

Thus the result should be recorded as

$$V = 47.7 \pm 0.6 \text{ cm}^3$$

(iv) **Write the dimensions of (a) Pressure (b) Density**

Ans **(a) Dimension of Pressure:**

$$\text{Dimension of pressure} = \frac{\text{Dimension of force}}{\text{Dimension of area}}$$

As $$P = \frac{F}{A} = \frac{ma}{A}$$

$\therefore$ $$\text{Dimension of pressure} = \left[\frac{MLT^{-2}}{L^2}\right]$$

or $$[P] = [MLT^{-2}][L^{-2}]$$

or $$[P] = [M][L^{-1}][T^{-2}]$$

Hence, $$\boxed{[P] = [ML^{-1}T^{-2}]}$$

(b) Dimension of Density:

As $$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{M}{V}$$

$$\text{Dimension of density} = \left[\frac{M}{L^3}\right]$$

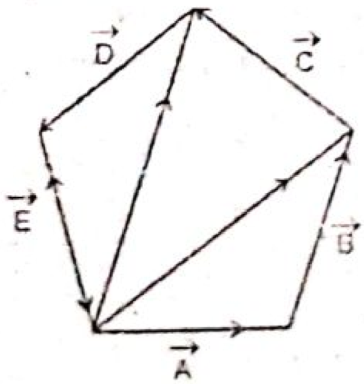
or $$[\rho] = \left[\frac{M}{L^3}\right]$$

$$= [M]\{L^{-3}\}$$

Hence, $$[\rho] = [ML^{-3}]$$

(v) **Suppose the sides of a closed polygon represent vectors arranged by head to tail. What is the sum of these vectors?**

Ans As we know that the resultant of a number of vectors which make a closed path is equal to zero.



If the vectors $\vec{A}$, $\vec{B}$, $\vec{C}$, $\vec{D}$, and $\vec{E}$ are represented by the sides of a closed polygon, then they are added by

using head to tail rule. Thus, the sum will be zero because the tail of the first vector coincides (meets) with the head of last vector.

Hence,

$$\vec{A} + \vec{B} + \vec{C} + \vec{D} + \vec{E} = 0$$

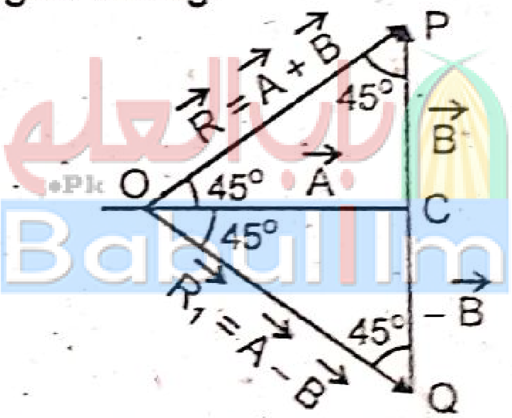
Hence, the sum of vectors of closed polygon becomes zero, because their resultant is represented in magnitude and direction by the closing side of the polygon taken in opposite order.

(vi). Show that the sum and difference of two perpendicular vectors of equal lengths are also perpendicular and of the same length.

Ans Consider two vectors $\vec{A}$ and $\vec{B}$ of equal lengths and perpendicular to each other. By head to tail rule, their sum

$$\vec{R} = \vec{A} + \vec{B} \text{ and difference } \vec{R}_1 = \vec{A} - \vec{B}$$

is showing in the fig.



In the right angled triangle OCP,

$$<P\hat{O}C = <O\hat{P}C = 45^\circ \qquad \ldots (1)$$

Similarly, in the other right angled triangle

$$<Q\hat{O}C = O\hat{Q}C = 45^\circ \qquad \ldots (2)$$

Adding the equation (1) and (2), we get

$$<P\hat{O}C + Q\hat{O}C = 45^\circ + 45^\circ = 90^\circ$$

$$\therefore \quad <P\hat{O}C + Q\hat{O}C = <P\hat{O}Q = 90^\circ$$

It means OP is perpendicular to OQ.

or $\vec{R}$ is perpendicular to R_1.

Hence, both $\vec{A} + \vec{B}$ and $\vec{A} - \vec{B}$ are perpendicular to each other.

Now, using the formula for magnitude of rectangular components *i.e.*,

$$R = \sqrt{(A)^2 + (-B)^2} = \sqrt{A^2 + B^2}$$

and $R^1 = \sqrt{(A)^2 + (-B)^2} = \sqrt{A^2 + B^2}$

Hence, magnitude (length) of $\vec{A} + \vec{B}$ is equal to the magnitude (length) of $\vec{A} - \vec{B}$, *i.e.*, both have the same length.

(vii) If $\vec{A} = 2\hat{i} - 2\hat{j}$, then what will be the orientation of $\vec{A}$?

Ans

$$\vec{A} = 2\hat{i} - 2\hat{j}$$

$$|A| = \sqrt{(2)^2 + (2)^2}$$

$$|A| = \sqrt{4 + 4}$$

$$|A| = \sqrt{8}$$

$$|A| = 2\sqrt{2}$$

$$A = \frac{\vec{A}}{|A|}$$

$$= \frac{2\hat{i} - 2\hat{j}}{2\sqrt{2}}$$

$$= \frac{\cancel{2}\hat{i}}{\cancel{2}\sqrt{2}} - \frac{\cancel{2}\hat{j}}{\cancel{2}\sqrt{2}}$$

$$\boxed{\hat{A} = \frac{\hat{i}}{\sqrt{2}} - \frac{\hat{j}}{\sqrt{2}}}$$

(viii) Define impulse and show that, how it is related to linear momentum?

Ans **Impulse:**

"The impulse provided by a force is the product of force and time for which it acts."

It equals to change in momentum of the object.

$$\text{Impulse} = \vec{F} \times t = m\vec{v}_f - m\vec{v}_i.$$

$$\text{Impulse} = I = \text{force} \times \text{time}$$

$$I = F \times \Delta t$$

As we know that

$\because$ $(F = ma)$

$$= ma \times \Delta t$$

$\because$ $a = \dfrac{v_f - v_i}{t}$

$$I = m\left(\frac{v_f - v_i}{\cancel{t}}\right) \times \cancel{t}$$

$$I = m(v_f - v_i)$$

$$I = mv_f - mv_i$$

$$I = \Delta P$$

(ix) The horizontal range of projectile is four times of its height. What is the angle of projection of projectile?

Ans Angle of projection = θ = ?

Maximum height = $h = \dfrac{v^2 \sin^2\theta}{2g}$

Range of projectile = $R = \dfrac{v^2 \sin 2\theta}{g}$

According to the question,

$$4h = R$$

Putting the values, we get

$$4\left(\frac{v^2 \sin^2\theta}{2g}\right) = \frac{v^2 \sin 2\theta}{g}$$

$$\frac{4}{2}\left(\frac{\sin^2\theta}{g}\right) g = \frac{v^2 \sin 2\theta}{v^2}$$

$$2\sin^2\theta = \sin 2\theta$$

$$2\sin^2\theta = 2\sin\theta\cos\theta$$

$$\frac{2\sin^2\theta}{2\sin\theta\cos\theta} = 1$$

$$\frac{\sin\theta}{\cos\theta} = 1$$

$$\tan\theta = 1$$

$$\theta = \tan^{-1}(1)$$

$$\theta = 45^\circ$$

(x) What is the principle of rocket propulsion?

Ans The motion of a rocket is an application of the law of conservation of momentum and Newton's third law of motion. A rocket has combustion chamber in which liquid or solid fuel is burnt and jets of hot gases are ejected out with a very high velocity from an opening at the tail of the rocket. The gases rushed out from the rocket gain a downward momentum and the rocket moves upward to balance the momentum of gases.

(xi) Find the angle of projection of a projectile for which its height and range are equal.

Ans Angle of projection = θ = ?

$$\text{Height} = h = \frac{v_i^2\sin^2\theta}{2g}$$

$$\text{Range} = R = \frac{v_i^2\sin 2\theta}{g}$$

According to question,

$$h = R$$

$$\frac{\cancel{v_i^2}\sin^2\theta}{2\cancel{g}} = \frac{\cancel{v_i^2}\sin 2\theta}{\cancel{g}}$$

$$\frac{\sin^2\theta}{2} = \sin 2\theta$$

$$\frac{\sin^2\theta}{2} = 2\sin\theta\cos\theta$$

$$\frac{\cancel{\sin^2\theta}}{\cancel{\sin\theta}\cos\theta} = 4$$

$$\frac{\sin\theta}{\cos\theta} = 4$$

$$\tan\theta = 4$$

$$\theta = \tan^{-1}(4)$$

$$\boxed{\theta = 76^\circ}$$

(xii) Explain, what do you understand by the term viscosity?

Ans Viscosity measures, how much force is required to slide one layer of the liquid over another layer. Substances that do not flow easily, such as thick tar and honey, etc. have large coefficients of viscosity. Substances which flow easily, like water, have small coefficients of viscosity.

3. Write short answers to any EIGHT (8) questions: (16)

(i) State work energy principle, also write its relation.

Ans Work done on the body equals to the change in its kinetic energy.

Whenever work is done on a body, it increase its energy. For example, a body of mass m is moving with velocity v_i. A force F acting through a distance d increase the velocity to v_p, then from equation of motion:

$$2ad = v_f^2 - v_i^2$$

$$d = \frac{1}{2a}(v_f^2 - v_i^2)$$

From second law of motion,

$$F = ma$$

$$Fd = \frac{1}{2}m(v_f^2 - v_i^2)$$

$$Fd = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

$$F.d = \Delta K.E$$

$$\boxed{W = \Delta K.E}$$

(ii) An object has 1 J P.E. Explain, what does it mean?

Ans An object having 1 J of potential energy means that the work done stored in the object in the form of potential energy has the capacity to do work of 1 J.

For example, if an object is lifted up by a force of one Newton through a height of one meter, the work done is stored in the object as potential energy of one Joule. If the object is allowed to fall vertically downward, it has the capacity to do 1 Joule work.

(iii) A girl drops a cup from a certian height which breaks into pieces. What eneryg changes are involved?

Ans When a cup is dropped from certain height which breaks into pieces, the potential energy is changed into the kinetic energy. Sound and heat energy are also produced.

(iv) Find rotational K.E. of hoop.

Ans For Hoop,

$$I = mr^2$$

$$K.E_{rot} = \frac{1}{2} I\omega^2$$

$$= \frac{1}{2} (mr^2)\,\omega^2$$

$$= \frac{1}{2} mr^2\,\omega^2$$

$$\boxed{K.E_{rot} = \frac{1}{2} mv^2}$$

(v) Define angular displacement. How its direction can be found?

Ans Grasp the axis of rotation in right hand with fingers curling in the direction of rotation, the thumb points in the direction of angular displacement.

(vi) Show that orbital angular momentum $L_o = mvr$.

Ans Angular momentum is given as:

$$\vec{L} = \vec{r} \times \vec{p}$$

Magnitude of angular momentum is:

$$L_o = r\,p\sin\theta \qquad \text{(i)}$$

where θ is angle between r and p.

Linear momentum is given as:

$$\vec{p} = m\vec{v}$$

Magnitude of linear momentum is:

$$p = mv$$

Putting this value in (i),

$$L_o = r\,m\,v\sin\theta$$

Let the object is moving in such a way that

$$\theta = 90$$

$$L_o = m\,v\,r\sin 90^\circ$$

$$L_o = m\,v\,r\,(1)$$

$$L_o = m\,v\,r \quad \text{Hence Proved.}$$

(vii) Explain the relation between total energy, potential energy and K.E. of a body oscillating with SHM.

Ans For a body oscillating with SHM, the relation between potential energy, kinetic energy and total energy at any instant t is:

$$E_{total} = P.E + K.E$$

Since total energy of SHM remains constant, therefore, any decrease in K.E or P.E result increase in P.E or K.E, respectively.

During SHM, in the absence of frictional forces, the K.E and P.E are interchanged continuously from one form to another but the total energy remains constant. At mean position, the enrgy is totally kinetic, *i.e.*, K.E is maximum but P.E is zero. At extreme positions, the K.E is

completely changed into P.E *i.e.*, P.E becomes maximum but C.E is zero.

(viii) If a mass spring system is hung vertically and set into oscillations, why does the motion eventually stop?

Ans A damped oscillator eventually comes to rest as its mechanical energy is dissipated. Same is the case with mass hanging vertically with spring air resistance plays a vital role in dissipation of energy.

(ix) Does the acceleration of a simple harmonic oscillator remain constant during its motion? Is the acceleration ever zero? Explain.

Ans No, the acceleration of harmonic oscillator does not remain constnat during its motion.

The acceleration of a S.H. oscillator is given by:

$$a \propto -x$$

$$a = -(\text{constant})\ x$$

where x is the displacement from the mean position.

Since, the displacement changes continuously during SHM, so its acceleration does not remain constant. The value of acceleration at the mean position will be zero because at this position x = 0 and its maximum value will be at the extreme position.

(x) Describe the effect of density on speed of sound.

Ans At the same temperature and pressure for the gases having the same value of γ, the speed is inversely proportional to the square root of their densities $\left(v = \frac{\gamma p}{\rho}\right)$.

Thus, the speed of sound in hydrogen is four times its speed in oxygen as density of oxygen is 16 times that of hydrogen.

(xi) **How are beats useful in tuning musical instruments?**

Ans Beats are used to tune a string instrument, such as piano, or violin, by beating a note against a note of known frequency. The string can then be adjusted to the desired frequency by tightening or loosening it unit, no beats are heard.

(xii) **Explain, why sound travels faster in warm air than in cold air?**

Ans Speed of sound in air is $v = \sqrt{\frac{\gamma p}{\rho}}$, when the gas is heated its density decreases. Since, speed of sound is inversely proportional to the density. Thus, sound travels faster in warm air than in cold air.

4. Write short answers to any SIX (6) questions: 12

(i) **Why the centre of Newton rings is dark?**

Ans At the point of contact of the lens and the glass plate, the thickness of the film is effectively zero but due to reflection at the lower surface of air film from denser medium, an additional path difference of $\frac{\lambda}{2}$ is introduced. Consequently, the center of Newton's ring is dark due to destructive interference.

(ii) **Under, what conditions two or more sources of light behave as coherent sources?**

Ans Two or more sources of light behave as coherent sources, if they have no phase difference or have a constant phase difference between the waves emitted by them. It is produced by using single source to illuminate a screen containing two narrow slits.

(iii) **What is optical fibre? Write down two uses of fibre optics.**

Ans **Uses:**

1. The use of light as transmission carrier wave has many advantages over radio wave carriers. It has much wider bandwidth capability and safe from electromagnetic interference.
2. Fibre optics is also used to transmit light around corners and into unapproachable places, which are unobservable in normal conditions.

(iv) When the telescope is said to be in normal adjustment?

Ans When a very distant object is viewed, the rays of light coming from any its point are considered parallel and these parallel rays are converged by the objective to form a real image A′B′ at its focus. If it is desired to see the final image through eyepiece without any strain on the eye, the eyepiece must be placed so that the image A′B′ lies at its focus. The rays after refraction through the eyepiece will become parallel and the final image appear to be formed at infinity. In this condition, the image A′B′ formed by the objective lies at the focus of both the objective and eyepiece and the telescope is said to be in normal adjustment.

(v) Why would it be advantageous to use blue light with a compound microsope?

Ans For a better resolution, objective of large aperture and use of blue light of short focal length is recommended because blue light is less diffracted as, $\alpha_{min} = 1.22 \frac{\lambda}{D}$.

Here, λ should be small to get less value of α_{min}.

(vi) Define the term internal energy.

Ans The sum of all forms of microscopic kinetic and potential energies of the molecules of a substance is termed as internal energy of a substance.

(vii) Prove that the maximum efficiency is always less than one or 100%.

Ans According to second law of thermodynamics, some part of input energy always goes into the sink *i.e.*, low

temperature reservoir and get wasted. Hence, the efficiency is always less than 1%.

(viii) Why does the pressure of a gas in a car tyre increases when it is driven through some distance?

Ans When a car is driven through some distance, work done by the car is partly spent in overcoming the frictional force between the road and the car tyre. Some part of work done against friction is converted into heat which raises the temperature of the gas in a car tyre. As we know that pressure is directly proportional to absolute temperature at constant volume, therefore, the pressure must increase because the heat energy increases the velocity and collisions of gas molecules. As a result, molecular collisions against the walls of a tyre increase the pressure of air inside the tyre.

(ix) Specific heat of a gas at constant pressure is greater than specific heat at constant volume. Why?

Ans When a gas is heated at constant pressure, then the heat supplied is used in two days:

(i) Some part of heat is used in doing the external work to move the piston up against the constant atmospheric pressure.

(ii) The other part of heat is used to increase the internal energy and temperature.

If the same gas is heated at constant volume, no external work is done to expand the gas. The total heat supplied is used to increase the internal energy and temperature of the gas. This shows that more heat is required to heat the gas at constant pressure than at constant volume for the same rise of temperature. So, we conclude that specific heat at constant pressure is greater than the specific heat at constant volume *i.e.,* $C_p > C_v$.

SECTION-II

NOTE: Attempt any Three (3) questions.

Q.5.(a) Define scalar product of two vectors. Write down four characteristics of scalar product. (5)

Ans **Scalar or Dot Product**

The scalar product of two vectors **A** and **B** is written as **A . B** and is defined as:

$$\mathbf{A} \cdot \mathbf{B} = AB \cos \theta \qquad \dots \text{(i)}$$

where A and B are the magnitudes of vectors A and B and θ is the angle between them.

For physical interpretation of dot product of two vectors **A** and **B**, these are first brought to a common origin (Fig. a),

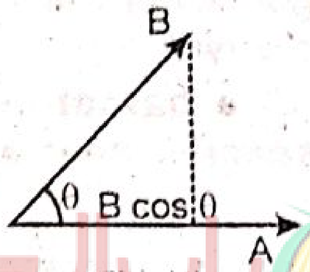


Fig. (a).

Then, $\mathbf{A} \cdot \mathbf{B}$ = (A) (projection of **B** on **A**)

or

$\mathbf{A} \cdot \mathbf{B}$ = A (magnitude of component of B in the direction of **A**)

$= A\,(B \cos \theta) = AB \cos \theta$

Similarly, $\mathbf{B} \cdot \mathbf{A} = B\,(A \cos \theta) = BA \cos \theta$

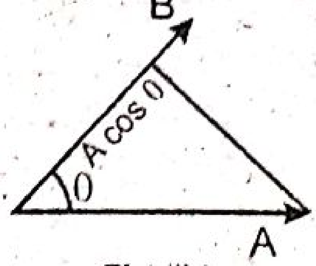


Fig. (b).

We come across this type of product when we consider the work done by a force **F** whose point of application moves a distance d in a direction making an angle θ with the line of action of **F**, as shown in Fig. (c).

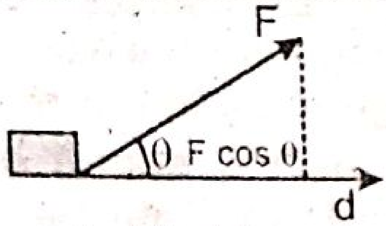


Fig. (c).

Work done = (effective component of force in the direction of motion) × distance moved

$$= (F \cos \theta)\, d = Fd \cos \theta$$

Using vector notation,

$$\mathbf{F.d} = Fd \cos \theta = \text{work done}$$

Characteristics of Scalar Product:

1. Since A.B = AB cops θ and B.A = BA cos θ = AB cos θ, hence, A.B = B.A. The order of multiplication is irrelevant. In other words, scalar product is commutative.

2. The scalar product of two mutually perpendicular vectors is zero, **A.B** = AB cos 90° = 0.

In case of unit vectors $\hat{i}$, $\hat{j}$ and $\hat{k}$, since they are mutually perpendicular, therefore,

$$\hat{i} \cdot \hat{j} = \hat{j} \cdot \hat{k} = \hat{k} \cdot \hat{i} = 0 \qquad \text{... (ii)}$$

3. The scalar product of two parallel vectors is equal to the product of their magnitudes. Thus for parallel vectors (θ = 0°)

$$\mathbf{A.B} = AB \cos 0^\circ = AB$$

In case of unit vectors,

$$\hat{i} \cdot \hat{i} = \hat{j} \cdot \hat{j} = \hat{k} \cdot \hat{k} = 1 \qquad \text{... (iii)}$$

and for anti-parallel vectors (θ = 180°)

$$\mathbf{A.B} = AB \cos 180^\circ = -AB$$

4. The self product of a vector **A** is equal to square of its magnitude.

$$\mathbf{A.A} = AA \cos 0^\circ = A^2$$

(b) A proton moving with the speed of $1.0 \times 10^7\ ms^{-1}$ passes through a 0.020 cm thick sheet of paper, and emerges with a speed of $2.0 \times 10^6\ ms^{-1}$. Assuming uniform deceleration. Find the retardation and time taken to pass through the paper. (3)

Ans **Given Data:**

Speed of proton = $V_i = 1.0 \times 10^7$ m/s

$S = 0.02$ cm

$= 0.0002$ m

Speed of proton = $V_f = 2.0 \times 10^6$ m/s

To find:

(a) retardation = a = ?

(b) time = t = ?

Calculation:

We have

$$2aS = V_f^2 - V_i^2$$

$$a = \frac{V_f^2 - V_i^2}{2S}$$

$$= \frac{(2.0 \times 10^6\ m/s)^2 - (1.0 \times 10^7\ m/s)^2}{2\ (0.0002)\ m}$$

$$= \frac{4 \times 10^{12}\ m^2/s^2 - 1 \times 10^{14}\ m^2s^2}{2 \times 2 \times 10^{-4}\ m}$$

$$= \frac{(4 - 1 \times 10^2)\ 10^{12}\ m^2/s^2}{4 \times 10^{-4}\ m}$$

$$= \frac{(4 - 100)\ 10^{12}\ m^2/s^2}{4m}$$

$$= \frac{-96}{4} \times 10^{16}\ m/s^2$$

$$= -24 \times 10^{16}\ m/s^2$$

$$\alpha = -2.4 \times 10^{17}\ m/s^2$$

(b) We have

$$V_f = V_i + at$$

$$t = \frac{V_f - V_i}{a}$$

$$= \frac{2.0 \times 10^6 \frac{m}{s} - 1.0 \times 10^7 \text{ m/s}}{-2.4 \times 10^{17} \text{ m/s}}$$

$$= \frac{(2 - 1 \times 10) \times 10^6 \text{ m/s}}{-2.4 \times 10^{17} \text{ m/s}^2}$$

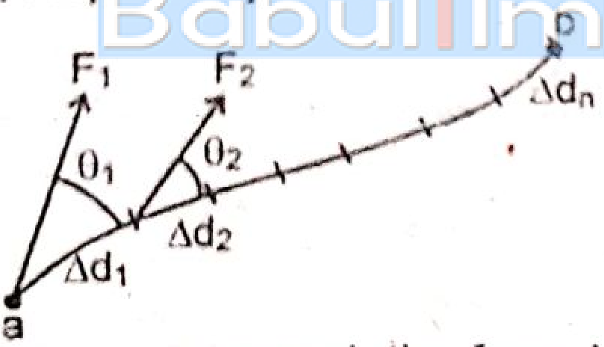
$$= \left(\frac{2 - 10}{-2.4}\right) \times 10^6 \times 10^{-17} \text{ sec.}$$

$$t = 3.33 \times 10^{-11} \text{ sec.}$$

Q.6.(a) What is variable force? Discuss work done by variable force. (5)

Ans Consider a force which is not constant. Let this force varies in magnitude only but its direction remains parallel to x-axis. A graph of such a motion is shown is Fig.

To calculate the work done, the path has been divided into n short intervals of displacements $\overrightarrow{\Delta d_1}$, $\overrightarrow{\Delta d_2}$,......, $\overrightarrow{\Delta d_n}$ and $\overrightarrow{F_1}$, $\overrightarrow{F_2}$, ..., $\overrightarrow{F_n}$ are the forces acting during these intervals, respectively.



During each small interval, the force is supposed to be approximately constant. So, the work done for the first interval can then be written as

$$W_1 = \overrightarrow{F_1} \cdot \overrightarrow{\Delta d_1} = F_1 \cos \theta_1 \, \Delta d_1$$

This work done W_1 is numerically equal to the shaded area of the rectangle.

The work done for the second interval can be written as:

$$W_2 = \vec{F_2} \cdot \Delta\vec{d_2} = F_2 \cos\theta_2 \Delta d_2$$

and is equal to the shaded area of the other rectangle. Similarly, the work done for the nth interval can be written as

$$W_n = \vec{F_n} \cdot \Delta\vec{d_n} = F_n \cos\theta_n \Delta d_n$$

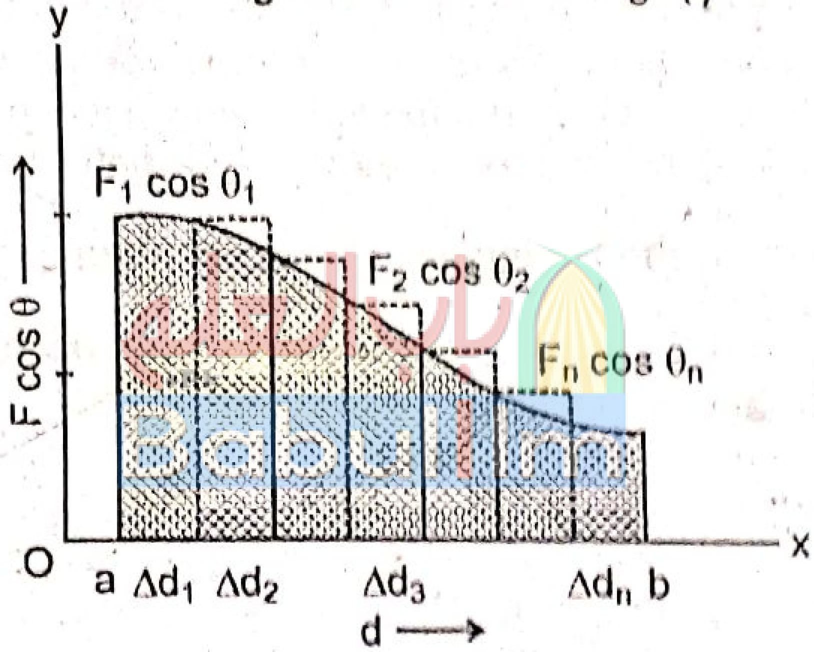
Thus, the total work done in displacing the body from point a to point b is given by

$$W_{total} = W_1 + W_2 + W_3 + \ldots\ldots + W_n$$

$$= F_1 \cos\theta_1 \Delta d_1 + F_2 \cos\theta_2 \Delta d_2 + \ldots\ldots$$

$$W_{total} = \sum_{i=1}^{n} F_i \cos\theta_i \Delta d_i \qquad \ldots \text{(i)}$$

This work done is approximately equal to the sum of areas of all the rectangles as shown in Fig. (i).

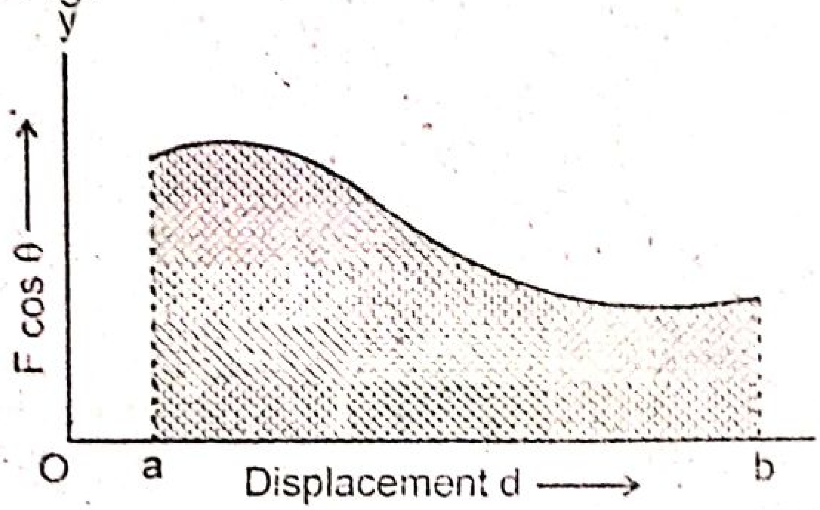


To get a more accurate result, we divide the total displacement into a very large number of equal intervals such that each Δd approaches zero as n approaches infinity. In this case, work done is given by

$$W_{total} = \lim_{\Delta d \to 0} \sum_{i=1}^{n} F_i \cos\theta_i \Delta d_i \qquad \ldots \text{(ii)}$$

Thus the work done by a variable force in moving a particle between two points is equal to the area under F

cos θ verses d curve between the two points a and b shown in Fig.



(b) The wavelength of signal from a radio transmitter is 1500 m and frequency is 200 kHz. What is wavelength for a transmitter operating at 1000 kHz and with what speed the radio waves travel?

Ans

Given Data:

Wavelength of signals = λ_1 = 1500 m

Frequency of signals = f_1 = 200 kHz = 200×10^3 Hz

Frequency of transmitter = f_2 = 1000 kHz

$f_2 = 1000 \times 10^3$ Hz

To find:

Wavelength for transmitter = λ_2 = ?

Speed of radio waves = V = ?

Calculations:

We know that

$$V = f\lambda$$

or $$V = f_1\lambda_1$$

$$V = 200 \times 10^3 \text{ Hz} \times 1500 \text{ m}$$

$$= 2 \times 10^5 \text{ s}^{-1} \times 1500 \text{ m}$$

$$V = 3 \times 10^8 \text{ ms}^{-1}$$

∴ Speed of radio waves = V = 3×10^8 ms^{-1}

As the transmitter emits radio waves, so

$$V = f_2\lambda_2$$

or $\lambda_2 = \frac{V}{f_2}$

$$\lambda_2 = \frac{3 \times 10^8 \text{ ms}^{-1}}{1000 \times 10^3 \text{ Hz}}$$

$$\lambda_2 = \frac{3 \times 10^8 \text{ ms}^{-1}}{10^8 \text{ s}^{-1}}$$

$$\lambda_2 = 3 \times 10^2 \text{ m} = 300 \text{ m}$$

Q.7.(a) Define centripetal force with an example. Prove that the magnitude of centripetal force is $F_c = mr\omega^2$. (5)

Ans "The force needed to bend the straight path of the particle into a circular path is called centripetal force."

If the particle moves from A to B with uniform speed "v" as shown in fig., the velocity of the particle changes its direction but not its magnitude. The change in velocity is shown in fig.

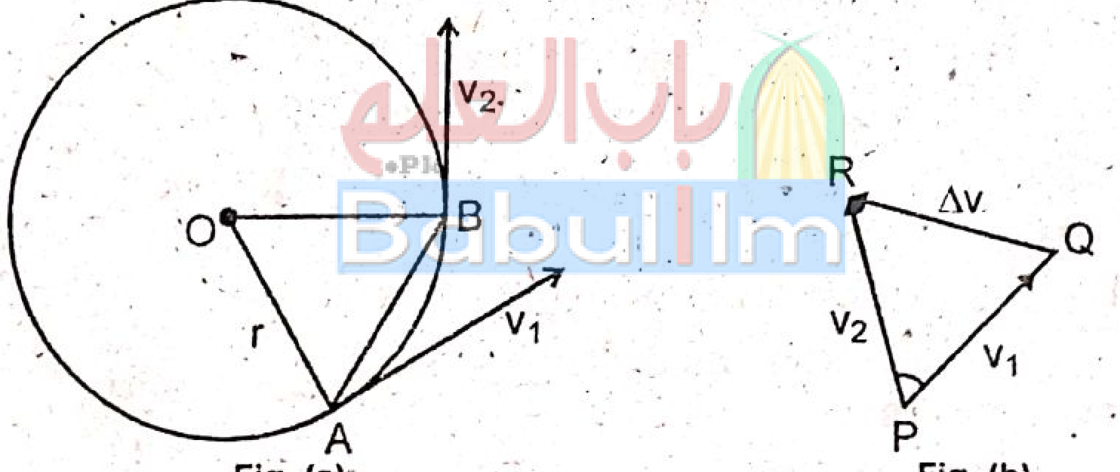


Fig. (a). Fig. (b).

Hence, the acceleration of the particle is

$$a = \frac{\Delta v}{\Delta t}$$

where Δt is the time taken by the particle to travel from A to B. Suppose at A the velocity is v_1 and at B the velocity is v_2. Since the speed of the particle is S, so the time taken to travel a distance s, as shown in fig. (a) is

$$\Delta t = \frac{S}{v}$$

So $\quad a = v\dfrac{\Delta v}{S}$ ... (i)

Consider the Fig. (b) in which PQ is the reference line for the velocity v_1 and PR is the reference line for the velocity v_2. Also in Fig. (a), the OA (radius of the circle) is perpendicular to its tangent v_1 and OB is perpendicular to v_2 also we know that in magnitude

$$v_1 = v_2 = v$$

and $\quad OA = OB$

In fig. (a), the triangle AOB and in fig. (b), the triangle PQR are isosceles. It means two isosceles triangles are similar, if the angles between their equal sides are equal.

So, we can take the ratio.

$$\frac{\Delta v}{v} = \frac{AB}{r}$$

Now, if the two points in fig. (a), A and B come very close to each other and in case $\Delta t \rightarrow 0$, only then the length AB was the same length as the line AB, so we can take

$$AB = S$$

So after rearranging the terms, we have:

$$\Delta v = S\frac{v}{r}$$

Putting this value for Δv in eq. (i), we get

$$a = \frac{v^2}{r} \qquad \text{... (ii)}$$

Here "a" is the instantaneous acceleration. This acceleration is caused by the centripetal force. So, it is called the centripetal acceleration and is represented by "a_c". Its direction is along the radius and towards the centre of the circle.

In Fig. (a) and (b), we know that PQ is perpendicular to OA, and PR is perpendicular to OB, so OR is perpendicular to AB. As the acceleration of the object moving in the circle is parallel to Δv when $AB \rightarrow 0$. Therefore, we can say that centripetal acceleration is

directed along radius towards the center of the circle. So, we can define the centripetal acceleration in these words.

"The instantaneous acceleration of an object travelling with uniform speed in a circle is directed towards the center of the circle and is called centripetal acceleration."

Centripetal force has the same direction as the centripetal acceleration and its value is given by the help of Newton's 2nd law of motion.

$$F = ma$$

By eq. (ii), we have

$$F_c = \frac{mv^2}{r} \quad \text{... (iii)}$$

In angular measure, we have

$$F_c = mr\omega^2 \quad \text{... (iv)}$$

(b) What gauge pressure is required in the city mains for a stream from a fire hose connected to the mains to reach a vertical height of 15 m? (3)

Ans **Given Data:**

$\Delta h = 15\text{ m}$

$g = 9.8\text{ m/s}^2$

Density of water $= \rho = 1000\text{ kg/m}^3$

To find:

Pressure = P = ?

Calculations:

According to Bernoulli's equation,

$$P_1 + \frac{1}{2}\rho V_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho V_2^2 + \rho g h_2$$

or $$P_1 - P_2 = \rho g h_2 + \frac{1}{2}\rho V_2^2 - \rho g h_1 - \frac{1}{2}\rho V_1^2$$

or $$P_1 - P_2 = \rho g (h_1 - h_2) + \frac{1}{2}\rho(V_1^2 - V_2^2)$$

or $$P = \rho g (h_1 - h_2) + \frac{1}{2}\rho(V_1^2 - V_2^2)$$

As throughout the speed does not change, hence

$$V_2^2 - V_1^2 = 0$$

So, above equation becomes

$$P = \rho g \Delta h$$

or $$P = 1000 \times 9.8 \times 15$$

$$= 14700 \text{ Pa}$$

or $$= 1.47 \times 10^5 \text{ Pa}$$

Q.8.(a) Define molar specific heat of a gas and prove that $C_p - C_v = R$. **(5)**

Ans **Molar specific heat:**

"The molar specific heat of a substance is defined as the heat required to raise the temperature of one mole of a substance through 1 K."

Derivation of $C_p - C_v = R$:

When one mole of a gas is heated at constant pressure, the internal energy increases by the same amount as at constant volume for the same rise in temperature ΔT.

$$\Delta U = C_v \ \Delta T \qquad (1)$$

Since, the gas expands to keep the pressure constant, so it does work $W = P\ \Delta V$, where ΔV is the increase in volume.

Substituting the values of heat transfer Q_p, internal energy ΔU and the work done W, we get

$$Q = \Delta U + W \qquad (2)$$

So, at constant pressure $Q_p = C_p \Delta T$ (3)

So, put values in eq (2)

$$C_p\ \Delta T = C_v\ \Delta T + P\Delta V \qquad (4)$$

Using equation 6 for one mole of an ideal gas,

$$PV = RT \qquad (5)$$

At constant pressure P, amount of work done by one mole of a gas due to expansion ΔV caused by the rise in temperature ΔT is given by eq. (2)

$$P\ \Delta V = R\ \Delta T$$

Substituting for $P\ \Delta V$ in eq. (1)

$$C_p \Delta T = C_v \Delta T + R \Delta T$$

or $$C_p = C_v + R$$

or $$C_p - C_v = R \qquad (6)$$

It is obvious from eq. (3) that $C_p - C_v$ by an amount is equal to universal gas constant R.

(b) A spring whose spring constant is 80 Nm^{-1} vertically supports a mass of 1.0 kg in the rest position. Find the distance by which the mass must be pulled down, so that on being released it may pass the mean position with a velocity of 1.0 m/sec. (3)

Ans $k = 80.0\ Nm^{-1}$, $m = 1.0\ kg$

Since $\omega^2 = \frac{k}{m}$

or

$$\omega = \sqrt{\frac{k}{m}}$$

$$= \sqrt{\frac{80\ Nm^{-1}}{1\ kg}} = \sqrt{\frac{80\ kg\ ms^{-2} \times m^{-1}}{1\ kg}}$$

$$= 8.94\ s^{-1}$$

Let the amplitude of vibration be x_o

Then $v = x_o \omega$ or $x_o = \frac{v}{\omega}$

as $v = 1.0\ ms^{-1}$ and $\omega = 8.94\ s^{-1}$

Distance through which m is pulled $= x_o = \frac{1\ ms^{-1}}{8.94\ s^{-1}}$

$$= 0.11\ m$$

Q.9.(a) What is Astronomical Telescope? Describe its construction and working. Derive a formula to calculate its magnification power. (5)

Ans **Astronomical Telescope**

It is an optical instrument used to see distant objects. The image of the distant object viewed through an

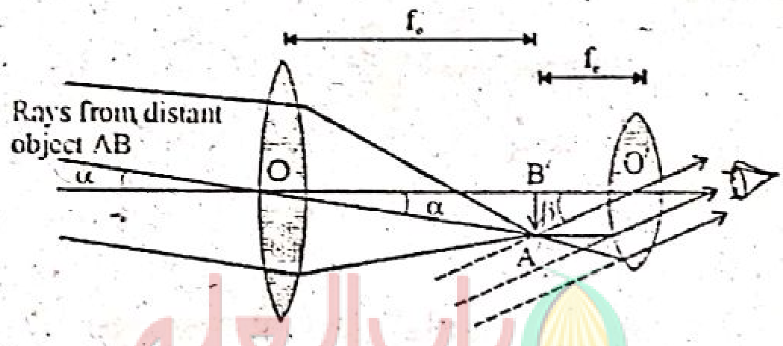
astronomical telescope appears larger because it subtends a bigger visual angle than when viewed with the unaided or naked eye.

Construction:

It consists of two double convex lenses. The one towards the object is called the objective and the one towards the eye is called eyepiece. The focal length of the objective f_o is greater than that of the eyepiece f_e.

The objective forms a real, inverted and diminished image A′B′ acts as an object for the eyepiece which is used as a magnifying glass. The final image seen through the eyepiece is virtual, enlarged and inverted.

The ray diagram for an astronomical telescope is shown in fig. below:



Working:

The object lies away from $2F_o$. The image A′B′ is formed on the other side between F_o and $2F_o$. Image is real, inverted and smaller in size. The eyepiece is placed in such a way that the image A′B′ formed by the objective lies within its pole and focus. The eyepiece serves as a magnifying glass, the final, virtual and magnified image thus formed is shown in the figure above. A′B′ is the image formed by the objective lies at the focus at both the objective and the eyepiece and the telescope is said to be in normal adjustment.

Whenever a telescope is to be using, before use it is always focused at infinity *i.e.,* the parallel rays are coming from infinity converge at the focus of the objective, then they become parallel to each other after passing through

the eyepiece because that point is also the focus of the eyepiece.

Calculation of the Magnifying Power:

Let us calculate the magnifying power of an astronomical telescope in normal adjustment. The angle α subtended at the unaided eye is practically the same as subtended at the objective and it is equal to $\angle A'O'B'$.

Therefore,

$$\alpha = \tan \alpha$$

From the triangle O'A'B'

Here, A'B' = perpendicular

and O'B' = base

Therefore,

$$\alpha = \tan \alpha = \frac{A'B'}{B'}$$

$$= \frac{A'B'}{f_o}$$

Because $O'B' = f_o$

Also, the angle β subtended at the eye by the final image is equal to $<A'O'B'$. Therefore,

We have another triangle O'A'B'. From this triangle, we can get

A'B' = Perpendicular

O'B' = Base

Therefore,

$$\beta = \tan \beta$$

$$= \frac{A'B'}{O'B'}$$

and $O'B' = f_e$

Hence, $$\beta = \frac{A'B'}{f_e}$$

We know the magnifying power of the astronomical telescope is given by

$$M = \frac{\beta}{\alpha}$$

$$= \frac{\frac{A'B'}{f_e}}{\frac{A'B'}{f_o}}$$

$$M = \frac{f_o}{f_e} \qquad \dots \text{(i)}$$

Here, $M = \dfrac{\text{Focal length of the objective}}{\text{Focal length of the eyepiece}}$

(b) In a double slit experiment, the second order maximum occurs at $\theta = 0.25°$. The wavelength is 650 nm. Determine the slit separation. (3)

Ans For Answer see Paper 2019 (Group-I), Q.9.(b).